ASSESSING AND EXPANDING CO$_2$ STORAGE CAPACITY IN DEPLETED AND NEAR-DEPLETED OIL RESERVOIRS

Prepared for:

International Symposium on Site Characterization for CO$_2$ Geological Storage (CO2SC)

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March 20-22, 2006
Berkeley, CA

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OUTLINE FOR DISCUSSION

1. **Attributes of Oil Reservoirs**

2. **Key Issues for Integrating CO_2 Storage and CO_2-EOR**

3. **An Initial Perspective of CO_2 Storage Capacity and CO_2-EOR Potential**

4. **Expanding CO_2 Storage**

5. **Summary**

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ATTRIBUTES OF OIL RESERVOIRS

Existing depleted and near-depleted oil reservoirs have numerous attributes that would make them preferred sites for geological storage of CO_2.

1. ***Established Secure Trap.*** An oil reservoir has accumulated and holds fluids for millions of years, thus providing:

  - Confidence in the integrity of the reservoir seal

  - Assurance of permanence of the fluid trap

As such, CO_2 injected into an oil reservoir, as long as the injected CO_2 volumes do not exceed the spill point, will likely remain "permanently" trapped and stored.

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ATTRIBUTES OF OIL RESERVOIRS (Cont'd)

*2.   **Value-Added Products.*** In geologically favorable settings, injecting CO_2 into a near-depleted oil reservoir can mobilize and recover significant volumes of additional oil using enhanced oil recovery technology (EOR):

- This would provide revenues for offsetting some (or all) of the costs of storing CO_2.

- The U.S. and many other parts of the world have large, mature oil fields with reservoir properties favorable for combining storage of CO_2 with CO_2 enhanced oil recovery.

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ATTRIBUTES OF OIL RESERVOIRS (Cont'd)

3. **_Existing Infrastructure._** In many cases, much of the essential requirements and infrastructure (such as wells, surface facilities, land access, mineral rights) already exists for storing CO_2. As such:

- The initial capital requirements for establishing a CO_2 storage facility would be lower than with an alternative option.

- The permitting, land disturbance and public acceptance aspects of CO_2 storage would be more favorable in areas already developed and comfortable with injection of fluids into the subsurface.

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KEY ISSUES FOR INTEGRATING CO_2 STORAGE AND CO_2-EOR

Given the many compelling reasons for using depleted and near-depleted oil reservoirs for CO_2 storage, the presentation addresses:

1. *What is the set of reservoir and fluid properties that would assist integrating CO_2 storage with CO_2-EOR?*

2. *How might one proceed with assessing CO_2 storage capacity with "value-added" oil production?*

3. *What opportunities exist for expanding and maximizing the CO_2 storage capacity offered by oil reservoirs?*

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AN INITIAL PERSPECTIVE OF CO_2 STORAGE CAPACITY AND CO_2-EOR POTENTIAL

Our company, Advanced Resources International, recently completed a series of ten "basin studies" that provide an initial perspective on the CO_2 storage potential from combining CO_2 storage and CO_2-EOR. The studies:
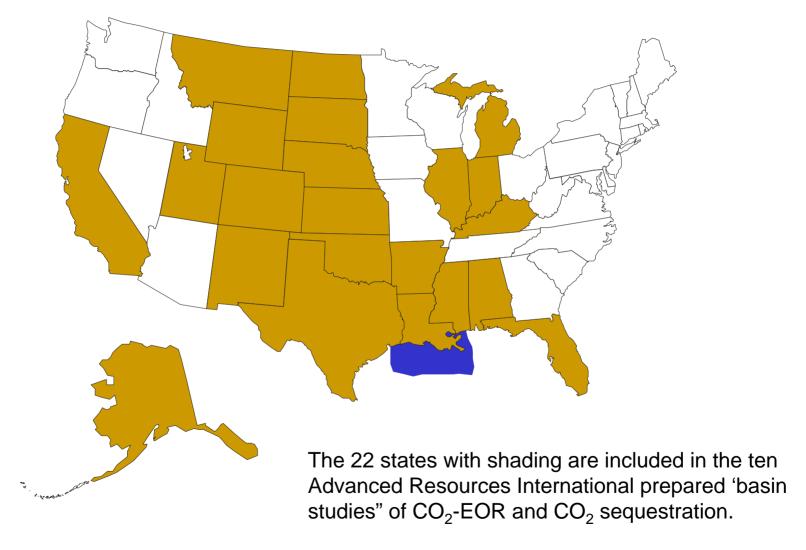
- Cover 22 of the oil producing states plus offshore Louisiana,

- Include 1,581 large (>50 MMBbls OOIP) oil reservoirs, accounting for two thirds of U.S. oil production,

- Estimated CO_2 storage capacity using a streamline reservoir simulation and an extensive data base of reservoir properties.

These reports are available on the U.S. Department of Energy's web site at http://www.fe.doe.gov/programs/oilgas/eor/Ten_Basin-Oriented_CO2-EOR_Assessments.html

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U.S. BASINS/REGIONS STUDIED FOR FUTURE OIL RECOVERY AND CO$_2$ SEQUESTRATION POTENTIAL FROM CO$_2$-EOR

The 22 states with shading are included in the ten Advanced Resources International prepared 'basin studies" of CO$_2$-EOR and CO$_2$ sequestration.

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AN INITIAL PERSPECTIVE OF CO_2 STORAGE CAPACITY AND CO_2-EOR POTENTIAL (Cont'd)

The 20 billion metric tons of CO_2 needed, of which about 80% would be stored as part of CO_2-EOR. Currently known natural CO_2 sources hold about 2 billion metric tons.

	Recoverable Oil	Purchased CO_2 Requirements	
	(Billion Barrels)	(Tcf)	(Billion Tonnes)
Technically Recoverable	89	377	20
Economically Recoverable			
• Mod Oil Price/High Cost CO_2 *	23	85	4
• High Equivalent Oil Price/High Cost CO_2 **	40	153	8
• High Equivalent Oil Price/Low Cost CO_2 ***	47	188	10

* $30 per bbl oil price, CO_2 cost of $1.50/Mcf, ROR of 15% before tax.

** $40 per bbl oil price, CO_2 cost of $2.00/Mcf, ROR of 15% before tax.

*** $40 per bbl oil price, CO_2 cost of $0.80/Mcf, ROR of 15% before tax.

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EXPANDING CO_2 STORAGE

The volume of CO_2 purchased for (and stored by) CO_2-EOR, as set forth in the ten "basin studies" assumes:

- Primary objective is enhancing economic oil recovery (minimizing costs while optimizing oil production).

- No economic value or benefit is placed on "permanently" storing CO_2.

As such, the above CO_2 requirements and storage volumes represent a <u>minimum</u>. The remainder of the paper examines how and by how much this <u>minimum volume</u> could be expanded.

EXPANDING CO_2 STORAGE: A CASE STUDY

To examine the "how and by how much" question for expanding CO_2 storage, we use a case study of a large, 340 million barrels of original oil in-place Gulf Coast oil reservoir with a main pay zone (producing oil-water contact), an underlying transition /residual oil zone and a strong bottom water aquifer:

- Main Pay Zone:
    - Depth - - 14,000 feet
    - Porosity - - 29%
    - Net Pay - - 325 feet
    - Initial Pressure - - 6,620 psi
- Transition/Residual Oil Zone (130 feet)
- Underlying Saline Aquifer (195 feet*)

*Within the spill point of the reservoir structure.

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EXPANDING CO_2 STORAGE: A CASE STUDY (Cont'd)

First, this Gulf Coast oil reservoir is produced using conventional (state-of-the-art) CO_2-EOR project design, targeting the main pay zone (MPZ), with vertical wells, and 1 HCPV of CO_2 with a 1:1 WAG (including both purchased and recycled CO_2).

The CO_2 storage and oil recovery results from this "conventional practices" CO_2-EOR design are as follows:

- CO_2 Purchased - - 424 Bcf (22.4 million tonnes)

- Oil Recovery - - 64 million barrels

- CO_2/Oil Ratio - - 6.6

- CO2 Stored* - - 350 Bcf (18.6 million tonnes)
  *CO2 storage is 83% of purchased CO2.

Under this design, only about 13% of the theoretical storage capacity (available pore space) in the reservoir is used for CO_2 storage.

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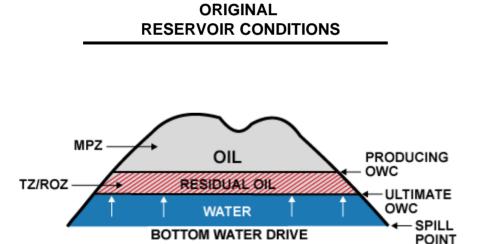# EXPANDING CO$_2$ STORAGE: A CASE STUDY (Cont'd)

Next, this Gulf Coast oil reservoir is produced using "next generation" CO$_2$-storage and CO2-EOR project design. This alternative design includes:

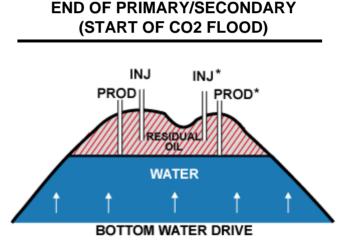- Targeting the main pay zone plus the transition/residual oil zone and the underlying saline aquifer.

- Conducting a gravity-stable, vertical CO$_2$ injection with horizontal wells.

- Injecting continuous CO$_2$ (no water)

- Continuing to inject CO$_2$ after completion of oil recovery, until maximum allowed reservoir pressure is reached.

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EXPANDING CO$_2$ STORAGE: A CASE STUDY (Cont'd)

The objectives of primary/secondary oil production and the conventionally designed CO$_2$-EOR project are to efficiently produce oil, avoid excessive production of water and minimize the use of purchased CO$_2$.
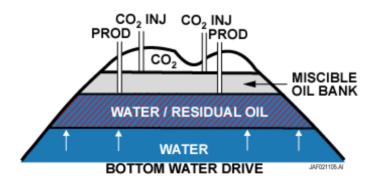

ORIGINAL RESERVOIR CONDITIONS

END OF PRIMARY/SECONDARY (START OF CO2 FLOOD)

*Our case study modified this design by using horizontal wells.

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EXPANDING CO$_2$ STORAGE: A CASE STUDY (Cont'd)

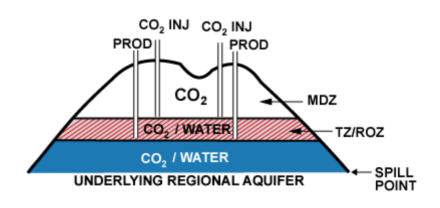The objectives of the "next generation" CO$_2$ storage and EOR project are to maximize both CO$_2$ storage and oil recovery.

CONVENTIONAL CO$_2$-EOR
TERMINATION CONDITIONS

"NEXT GENERATION"
TERMINATION CONDITIONS

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EXPANDING CO$_2$ STORAGE: A CASE STUDY (Cont'd)

Compared to the conventional CO$_2$-EOR design, considerably more CO$_2$ storage is possible in this reservoir with "next generation" design. An added bonus is that oil recovery and recovery efficiency are also increased.

	MPZ	TZ/ROZ	Aquifer	TOTAL
CO$_2$ Stored (Bcf)				
• Bcf	1,150	410	500	2,060
• Million Tonnes	61	22	26	109
Oil Recovery (million barrels)	112	68	--	180

Under this scenario, 76% (instead of 13%) of the reservoir's theoretical storage capacity is used for CO$_2$ storage. Oil recovery is 180 million (instead of 64 million) barrels, providing an additional 116 million barrels.

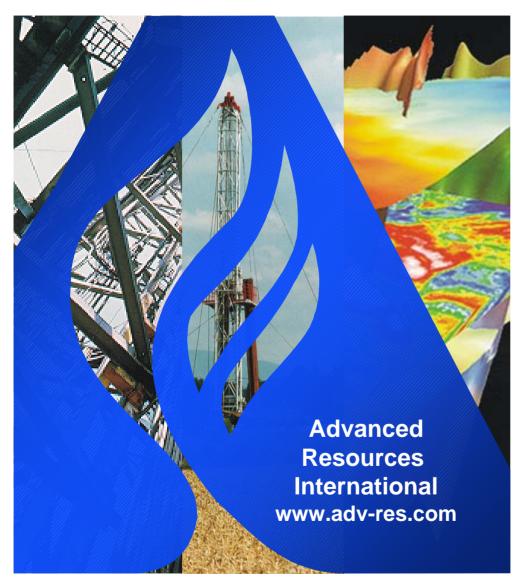*Advanced Resources International, Inc.*

SUMMARY

Depleted and near-depleted oil reservoirs have numerous attributes that make them attractive for storing CO_2 - - an established, secure trap; "value-added" products; and, existing infrastructure.

Even using today's "state-of-the-art" CO_2-EOR practices, the case study shows that a small portion - - 13% - - of the available CO_2 storage capacity in the oil reservoir is productively used.

Applying "next generation" practices that integrate the storage of CO_2 and oil recovery, a much greater portion - - 76% - - of the available CO_2 storage capacity may become useable.

The next step would be to apply the "lessons learned" from the case study to other basins and oil fields to help expand the CO_2 storage capacity offered by domestic oil reservoirs.

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